

Ordovician–Silurian boundary strata in Wales

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Synopsis

Ordovician–Silurian boundary strata in Wales belong to the shelly facies in the south and east, and to the graptolitic facies in the north and west. In the graptolitic facies the zones of *Dicellograptus anceps*, *Glyptograptus persculptus* and *Parakidograptus acuminatus* occur, but the *Climacograptus? extraordinarius* Zone is not known. The *anceps* Zone is restricted to central and west Wales; the *persculptus* Zone is widespread and is preceded by a sudden lithological change; the *acuminatus* Zone is preceded by a more gradual lithological change. Graptolites occur sporadically in boundary strata of the shelly facies but are not abundant enough for the base of the *acuminatus* Zone to be recognized in this facies. Records of the *Hirnantia* fauna in Wales are summarized.

Introduction

As a result of Caledonian and Hercynian folding the Ordovician–Silurian boundary strata in Wales form a complex arcuate pattern striking approximately NE–SW through much of central Wales but becoming east–west in south-west Wales and SE–NW in north-east Wales. The length of outcrop is approximately 750 km. The outcrop is shown in Fig. 1, together with index numbers by which individual areas and the references relating to them are cited in the text.

In places on the outward (S, SE or E) side of the Caledonian fold belt in Wales, as in the adjoining parts of England, the local base of the Silurian is formed by late Llandovery (post-*convolutus* or post-*sedgwickii*) or Wenlock strata transgressive onto pre-Ashgill strata. This relation is found in the southernmost outcrop (but not in the main northern outcrop) at Haverfordwest (1a), near Llandeilo (2), from north of Llandovery (4) to Garth (5a, b), near Builth Wells (6), east of Abbey-Cwmhir (7), and east of Welshpool (25, 26). Flanking this marginal area of late Llandovery transgression there is an unconformity of lesser magnitude between the early Llandovery and the Ashgill (and Caradoc) near Welshpool (27) and Llan-santffraid ym Mechain (31), and although the gap continues to diminish northwards and westwards it is recorded as still present in the Meifod and Vyrnwy areas (28, 29). Elsewhere in Wales the early Llandovery is believed to follow the topmost Ordovician with no sedimentary gap.

Boundary strata

Ordovician–Silurian boundary strata in Wales show two facies, shelly and graptolitic. The shelly facies consists of detrital sediments, mainly of the silt and sand grades, with a fauna predominantly of brachiopods. The graptolitic facies consists of fine detrital sediments (mudstones and shales) with some coarser horizons interpreted as turbidites, and with a fauna almost exclusively of graptolites.

In pre-*persculptus* Zone strata the dichotomy into shelly and graptolitic facies is not as clearly defined as later. The strictly graptolitic facies, as defined by the recorded presence of the *Dicellograptus anceps* Zone, is much more restricted in occurrence (to central and west Wales—16, 18, 19, 20) than the *persculptus* Zone, and even where both zones occur in the same area the intervening strata are either unfossiliferous (16, 18, 19) or include shelly fossils (20). Along the outcrop north-west of the Towy anticline (8–14), for instance, where the *persculptus* Zone is graptolitic, the very thick underlying strata yield only sporadic graptolites (not diagnostic of the *anceps* Zone), being otherwise unfossiliferous or with a few shelly fossils. The restriction of the demonstrable *anceps* Zone to central and west Wales and the wider extent eastwards of the *persculptus* and *acuminatus* Zones are consistent with regression during *anceps* Zone time followed by transgression during the *persculptus* Zone. The *extraordinarius* Zone has not been



Fig. 1 Ordovician-Silurian boundary outcrop areas in Wales and the Welsh Borderland. 1, Haverfordwest: 1a, Strahan *et al.* 1914; 1b, Cocks & Price 1975. 2, Llandeilo, Williams 1953. 3, 4, Llandoverly: 3a, Jones 1925; 3b, Jones 1949; 4, Cocks *et al.* 1984. 5, Garth: 5a, Andrew 1925; 5b, Williams & Wright 1981. 6, Builth Wells, Jones 1947. 7, Abbey-Cwmhir, Roberts 1929. 8, 9, Rhayader: 8, Lapworth 1900; 9, Kelling & Woollands 1969. 10, Rhayader to Abergwesyn, Davies 1928. 11, Abergwesyn to Drygarn, Davies 1926. 12, Pumpsaint, Davies 1933. 13, Llansawel, Drew & Slater 1910. 14, Llangranog, Hendricks 1926. 15, Llanidloes, Jones 1945. 16, Plynlimon, Jones 1909. 17, Machynlleth, Jones & Pugh 1916. 18, Towyn and Abergynolwyn, Jehu 1926. 19, Corris, Pugh 1923. 20, Dinas Mawddwy, Pugh 1928. 21, Llanuwchllyn-Llanymawddwy, Pugh 1929. 22, Bala: 22a, Elles 1922; 22b, Bassett *et al.* 1966. 23, Cerrigydrudion, Marr 1880. 24, Conwy, Elles 1909. 25, Shelve area, Whittard 1932. 26, 27, Welshpool: 26, Wade 1911; 27, Cave 1965. 28, Meifod, King 1928. 29, Lake Vyrnwy, King 1923. 30, Berwyns: 30a, Wedd *et al.* 1929; 30b, Brenchley & Cullen 1984. 31, Llansantffraid ym Mechain, Whittington 1938. 32, Llangollen: 32a, Groom & Lake 1908; 32b, Hiller 1980. 33, Corwen, Lake & Groom 1893. 34, Llangollen, Wills & Smith 1922. 35, Llangollen, Wedd *et al.* 1927. 36, Mynydd Cricor, Smith 1935. 37, Criccieth, Roberts 1967. 38, Anglesey, Greenly 1919. 39, W. Berwyn, A. W. A. Rushton & J. T. Temple (unpublished). 40, Aberystwyth and Machynlleth, Cave & Hains 1986.

recognized in Wales, but there is ample room for it: the barren strata between the *anceps* and *persculptus* Zones in areas 16, 18, 19, 20 are respectively 730 m, 1000 m, 690 m, and 180 m thick.

In the *persculptus* Zone and the succeeding early Llandovery the dichotomy into shelly and graptolitic facies is well shown. The shelly facies forms a narrow belt running through Haverfordwest (1a, b), the Llandovery (3a, b, 4) and Garth (5a, b) areas (which form north-westward salients from the adjacent line of outcrop along which the strata are missing), and the eastern end of the Berwyn dome (27–32, 34–36). The transition from shelly to graptolitic facies of the *persculptus* Zone and early Llandovery takes place in south and central Wales across the Towy anticline (between for instance Llandovery [3a, b, 4] and Pumpsaint [12]), and in north-east Wales probably north-westwards across the Berwyn dome. The *persculptus* and *acuminatus* Zones are widespread, having been recorded from north-west of the Towy anticline (10–12) as well as through most of central and west Wales (14–21, 40). *G. persculptus* occurs on the western outcrop around the Berwyn Hills at Nant Pant-y-llidiart, north of Lake Vyrnwy (39), and there is an informal record of the species at Bwlch yr Hwch, 5 km SE of Bala (Jones *in Pugh*, 1929: 274–5). The *persculptus* Zone (but not the *acuminatus* Zone) has also been recorded from the north end of the Towy anticline (7, 9), and *G. cf. persculptus* occurs at Garth (5a). The early Llandovery graptolite succession between Bala (22a, b) and Conwy (24) is still in need of reinvestigation. In the two small isolated outliers near Criccieth (37) and in Anglesey (38) the early Llandovery is in graptolite facies, but in both cases the relationship to the Ordovician is obscure and neither the *persculptus* nor the *acuminatus* Zones are recorded.

A sudden and striking lithological change heralds the incoming of *persculptus* Zone graptolites in west and central Wales (14–20, 40): the underlying strata are very thick, usually unfossiliferous, often unbedded, well cleaved or doubly cleaved, and with many 'grit' bands; the *persculptus* Zone strata (the 'Mottled Beds') are mudstones 5–25 m thick, well-bedded, often with mottled pale bands (interpreted as bioturbated—Cave & Hains 1986) and with a thin band crowded with the zone fossil about 1 m above the base. The suddenness of the lithological change preceding the appearance of *G. persculptus* in this part of Wales betokens some physical change in the conditions of deposition, and this evidence also is consistent with a *persculptus* transgression following regression. A similar lithological contrast at this horizon is also found north of the Towy anticline (9–11), although not strongly marked in the south of the outcrop (12).

There is also a lithological change below the *acuminatus* Zone in west and central Wales (15–20, 40), but it is more gradual than that below the *persculptus* Zone, the hard resistant mottled mudstones of the latter zone being gradually replaced by rusty red- and yellow-weathering mudstones without bioturbation (40). A similar change occurs at this horizon north of the Towy anticline (10–12). In both areas the change probably precedes the end of the *persculptus* Zone (40, 12).

Hirnantia fauna in Wales

Around the Berwyn dome and near Llangollen there are developed 'grits' which have been taken as either topmost Ordovician (35) or basal Silurian (28, 29): Craig-wen Sandstone (28), *Meristina crassa* Sandstone (29), Allt-gôch Grit (30), Corwen Grit (33), Glyn Grit (32), Plâs uchaf Grit (35). These grits have been interpreted as channel-fill deposits formed during the Hirnantian regression (30b). 'Grits', possibly of the same age as those around the Berwyns, also occur in the north and east of the Bala area (Calettwr Quartzite—22b) and along the little-known outcrops north of Bala, i.e. at Cerrigydrudion (23) and Conwy (Conwy Castle Grit—24). South of the Berwyns there are 'grit' bands near Abbey-Cwmhir (7) which are mapped as topmost Ordovician but whose relationship to the *persculptus* Zone strata occurring about 3 km to the west needs reinvestigation.

Many of the 'grits' in these different areas include elements of the *Hirnantia* fauna (Fig. 1), for which Brenchley & Cullen (1984: 122) give faunal lists at various Welsh localities. To these

authors' list for 'Meifod' (i.e. Craig-wen quarry, near Meifod) may be added the record of the tretaepid indet. discovered on the Silurian Subcommission excursion in 1979, although the presence of pebbles of underlying strata in the Craig-wen Sandstone suggests the possibility of this being a derived fossil. The *Hirnantia* fauna also occurs in Afon Tanat on the western outcrop of the Berwyn Hills (39). The *Hirnantia* fauna at its type area south of Bala (22a) was considered by Pugh (1929: 273) to be pre-*persculptus* in age although no single section (except Jones' record at Bwlch yr Hwch—see above—which awaits confirmation) shows the one fauna succeeding the other. Further southwestwards along the outcrop (beyond 20) in west and west-central Wales the *Hirnantia* fauna dies out while the *persculptus* Zone fauna becomes more clearly developed. South of the Towy anticline the *Hirnantia* fauna has been recorded from Garth (5a, b) apparently in association with *G. cf. persculptus* (Williams & Wright 1981: 38), and from Haverfordwest (1b) in the St Martin's Cemetery Beds (Cocks & Price 1975: 710) whose relations to the *persculptus* Zone are unknown. The *Hirnantia* fauna has also recently been found in the Llandovery area (4) where it is considered (Cocks *et al.* 1984: 144) to underlie strata probably representing the *persculptus* Zone.

At Conwy (24) the *Hirnantia* fauna is underlain, as in the English Lake District, by strata containing abundant *Dalmanitina* [*Mucronaspis* auctt.], and this relationship is found also at Bala (22a) and in the Llanuwchllyn-Llanymawddwy area to the south (21). The trilobite persists southwestwards along the outcrop, as the facies change and the rocks thicken, even further (20, ?19) than the *Hirnantia* fauna. On the other hand the *Hirnantia* fauna around the Berwyns (28–30), at Abbey-Cwmhir (7) and at Garth (5) is not accompanied or preceded by *Dalmanitina* (except for a possible record in area 28—King 1928: 687), and although the absence of the latter trilobite in the Berwyns may be due to a stratigraphical gap below the *Hirnantia* 'grits', there is no evidence for such a gap at Abbey-Cwmhir or Garth, nor indeed at Llandovery where *Dalmanitina* is also absent. At Haverfordwest (1b) *Dalmanitina* occurs as part of an unusually rich *Hirnantia* fauna but is not found in underlying strata.

Descriptions of sections

Boundary strata of four areas merit description: Plynlimon-Machynlleth (16, 17, 40), where the sequence is graptolitic throughout and where the *persculptus* and *acuminatus* Zones are well developed; Llandovery (3a, b, 4) where the base of the Llandovery was originally defined; Haverfordwest (1a, b) and Garth (5a, b), in both of which there are apparently continuous successions in strata of predominantly shelly facies.

Plynlimon-Machynlleth (16, 17, 40). The succession in this area, which is wholly in the graptolitic facies, has recently been described in detail (Cave & Hains 1986). The best sections of the Mottled Mudstone Member are at the Cardiganshire Slate Quarry (National Grid ref. SN 6991 9595) and in a stream near Eisteddfa-Gurig (SN 7951 8409), but the faunal transition between the *persculptus* and *acuminatus* Zones has not been investigated in detail.

70–145 m	Cwmere Formation	}	5–25 m	Strata above Mottled Mudstone Member. Dark grey rusty-weathering mudstones: in middle, sandstones and siltstones near top of <i>acuminatus</i> Zone.
				Mottled Mudstone Member. Banded mudstone with pale bioturbated layers and phosphatic concretions (both disappearing in topmost 3 m). The lowest beds are unfossiliferous but about 1 m above the base is a thin layer (15–30 cm) with abundant <i>G. persculptus</i> . Pyritized <i>G. persculptus</i> also occur above this layer.
	Bryn-glâs Formation			Massive mudstone with splintery, phacoidal cleavage.

Garth (5b). The following section is obtained by mapping in strata of predominantly shelly facies near Garth, 32 km NE of Llandovery, Powys (Williams & Wright 1981).

250 m +	Sandstones & mudstones	Rhuddanian shelly fossils
77 m +	Garth Bank Formation	
11–51 m	Cwm Clŷd Formation	<i>Eostropheodonta hirnantensis</i>
0–30 m	Wenallt Formation	Speckly Sandstone Member <i>Hirnantia</i> fauna. (Andrew [5a] records <i>G. cf. persculptus</i> and <i>Mesograptus cf. modestus parvulus</i> probably from this Member)
0–20 m		Ooid Member <i>Hirnantia</i> fauna
0–65 m		Siltstones <i>Brongniartella cf. robusta</i> (high Rawtheyan)

Llandovery (4). The following section (transect i_2 of Cocks *et al.* 1984) is exposed almost continuously along a forestry road in the north Llandovery area (base of section at Grid ref. SN 8467 3962). The *Hirnantia* fauna, however, is extrapolated from 1.3 km further west.

120 m	Bronydd Formation	Rhuddanian shelly fossils and graptolites suggesting <i>atavus</i> and <i>acinaces</i> Zones. Near base <i>Climacograptus normalis</i>
70 m	Scrâch Formation	(<i>Hirnantia</i> fauna in west)
—	Tridwr Formation	Rawtheyan shelly fossils and 'uppermost Ordovician' graptolites

Haverfordwest (1b). The following section (Cocks & Price 1975) is obtained by mapping in strata of predominantly shelly facies at Haverfordwest, Dyfed, but there are continuous exposures in road and railway sections upwards from about the middle of the Haverford Mudstone Formation (base of road section at Grid ref. SM 9573 1547).

85 m	Gasworks Sandstone Formation	Graptolites indicating <i>acinaces</i> or <i>atavus</i> Zones at top. Rhuddanian shelly fossils throughout
370 m	Haverford Mudstone Formation	Rhuddanian shelly fossils. <i>Climacograptus cf. normalis</i> near middle. ? <i>C. normalis</i> at 9 m above base
65 m	Portfield Formation	<i>Hirnantia</i> fauna at top, including Diplograptid undescr. sp.
—	Slade & Redhill Mudstone Formation	Rawtheyan shelly fossils

Conclusions

On the assumption (cf. Temple 1978) that graptolite zones are definable and recognizable entities, then because of the wide extent of the *persculptus* and *acuminatus* faunas in central Wales, the Ordovician–Silurian boundary defined beneath the *acuminatus* Zone is in principle widely applicable in Wales. It is not however directly applicable in the marginal belt characterized by boundary strata of shelly facies. Even in the recently reinvestigated Llandovery area (4), where there is an intermingling of shelly fossils and graptolites, the *persculptus* and *acuminatus* Zones are not firmly enough identified for the boundary to be recognized accurately.

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